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MOSAICKING OF THE 1:75 000 SHEETS OF THE THIRD MILITARY SURVEY OF THE HABSBURG EMPIRE

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The original map sheets of the Third Military Survey of the Austro-Hungarian Monarchy cannot be mosaicked in their original, printed form because of their uneven trapezoid format. To make a digitized raster mosaic of the individual sheets, they all should be georeferenced. Instead of the original projections, which vary from sheet to sheet, a series of sinusoid projections was defined, one unique projection for each sheet columns. The sinusoid projection provides an appropriate approximation of the original trapezoid forms and size of the sheets. Each sheet were rectified in the respective projection then reprojected to a general conic projection, defined for the final mosaic. After all of those transformations, the transformed digital content of the sheets fits to each other well enough to make a geo-referred mosaic. The location parameters of the geodetic datum used for transformation to modern projection systems are the followings: $dX = +600$ m; $dY = +205$ m; $dZ = +437$ m. These figures gives exact fit at the fundamental point of Hermannskogel. Because of the not unified geodetic adjustment of the original base point system, using one unified datum causes a maximum error of 220 meters throughout the whole territory of the Monarchy and the adjacent area on the maps.

Keywords: archive maps; Central Europe; georeference; Habsburg Empire; Third Military Survey

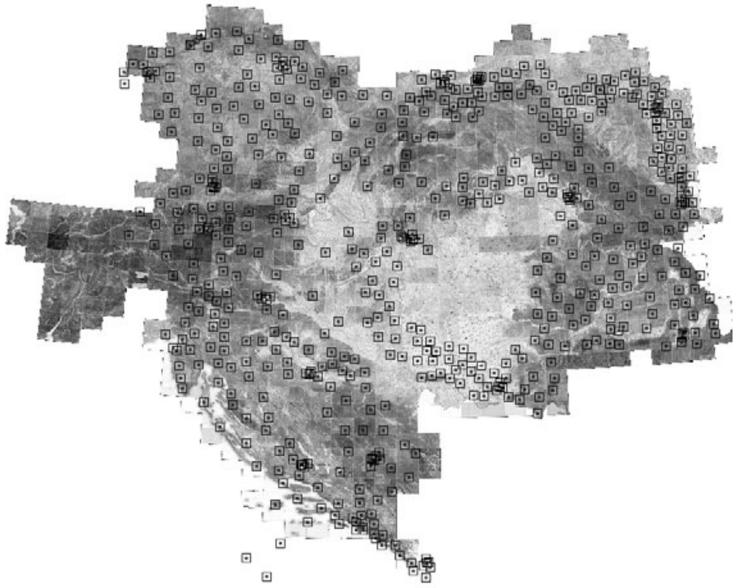

Fig. 1. The full mosaic of the Habsburg Empire on the 1:75 000 sheets of the Third Military Survey with the first-order triangulation points (Biszak et al. 2007)

Introduction

The second military surveying of the Habsburg Empire, which took some fifty years, was almost completed by the 1860s. Geodesy was undergoing tremendous development in the period of the survey. It was in this period of time when Karl Friedrich Gauss established the potential theoretical description of the Earth's figure as well as the method of geodetic network adjustment by the method of the least squares. Both the developments and the fact that in many cases the maps of the Second Military Survey had showed states of several decades earlier made it pressing to carry out a new survey in the Empire, today called the Third Military Survey. Survey map series on a scale of 1:25 000 and general map series on a scale of 1:75 000 were made within the framework of the survey.

The map sheets were first published and marketed in 1880, but they can be come across in second-hand bookshops even today. The map sheets' dates of issue were indicated in the bottom right corner. The sheets represent the Monarchy's entire territory often reaching beyond it along the borders (e.g. in the direction of Switzerland, Germany, Italy). Almost the whole of Montenegro and the north of Albania can be seen in the south. Later, a few years before World War I, and partly during the war, a new series of the sheets on a scale of 1:75 000 were completed with the represented territory going well beyond the borders of the Monarchy.

The rectified mosaic of the whole Monarchy is now available in 1:75 000 scale as the work of the Arcanum Database Ltd., Hungary (Biszak et al. 2007, Figs 1 and 2). In the present paper, we present the detailed method of the rectification and the mosaic making.

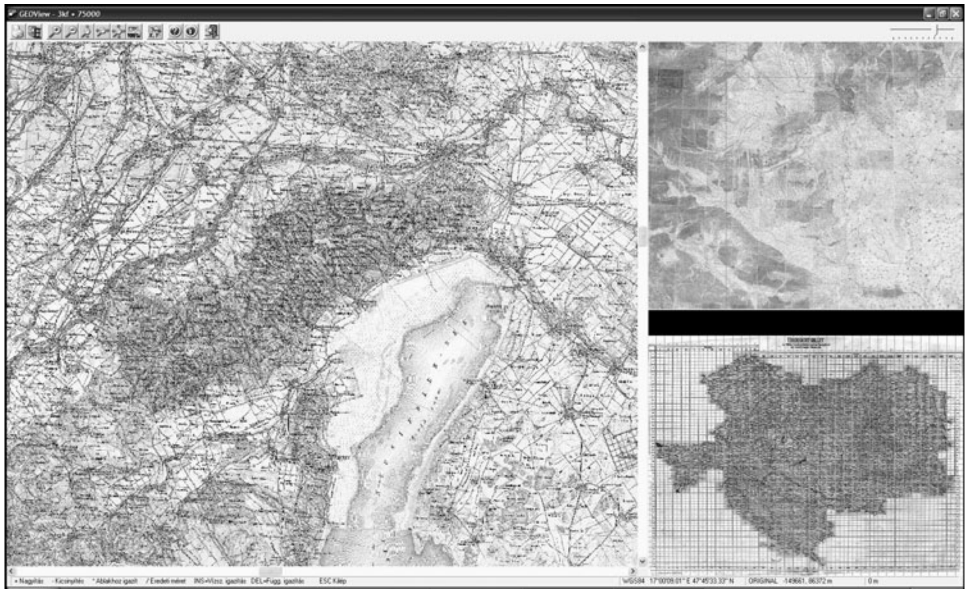

Fig. 2. Display view of the Arcanum software (Biszak et al. 2007), using the method described in this paper

The projection and georeferencing of the map series

The Third Military Survey's first sheets on a scale of 1:75 000, published in 1880, were designed in a fairly simplified way from the point of view of projection. Every individual map sheets were made in a local map projection. The intersection of the central meridian and parallel of the map sheet was chosen as the projection center. The parallels and meridians of the latitude-longitude grid represent the sheet boundaries. In practice, these are straight lines. Since the typical extent of a map sheet don't exceed 25×40 kilometers, and the bordering meridians are close to the projection center thus these bordering arcs were substituted with straight lines and the sheets have the shapes of a trapezoid (Sárói Szabó 1901, Balla and Hrenkó 1991, Veverka and Čechurova 2003, Kretschmer et al. 2004). On the editions published later (in the 1910s), the parallels forming the sheets' boundaries are curved.

Naturally, each sheet differs in size, except for those that have the same latitude. Consequently, a mosaic cannot be made from the sheets mechanically, by placing one sheet next to the other (Sárói Szabó 1901) (Fig. 3). Placing one sheet next to the other results a spatial surface. As this symmetrical spatial object consisting of many planar quadrangles is called polyhedron, this projection is often referenced as 'polyhedral'.

To create the mosaic on the DVD, we distorted the scanned picture of the original sheets in a way that they are placed into a uniform map projection. An explicit way of doing this would have been if an approximate projection for each sheet had been defined in GIS environment and each single sheet in this particular

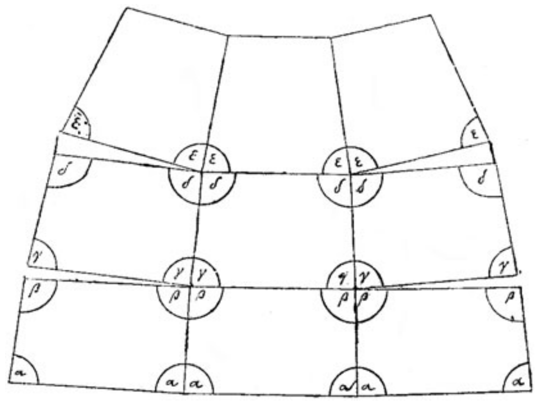

Fig. 3. The original structure of the sheets of the Third Military Survey (Sárói Szabó 1901)

projection had been georeferenced then the resulting file had been transformed into the common projection. Considering the large number of sheets, we scrapped this solution. Instead, for each sheet column we defined a substitute projection, which provides a distortion form quite similar to the shape of a trapezoid. We selected sinusoidal projection; with each column the projection center was the intersection of the column's central meridian and the Equator. We georeferenced each sheet in a projection selected for a particular column. We defined 6 GCPs per sheet: a sheet's edge points and the mid points of the northern and southern sheet boundaries. As a result, the sheets' original trapezoid shape could be followed with some 20 meters accuracy.

The map series were designed with the prime meridian of Ferro and throughout the georeferencing process we took the Ferro-Greenwich shift consistently as $17°40'$. During the unification process we switched over to the Greenwich prime meridian and we transformed the sheets into the Lambert Conformal Conic projection. The projection center is $\Phi_0 = 47°$; $\Lambda_0 = 19°$, while the two standard parallels are $\Phi_1 = 45°$ and $\Phi_2 = 49°$.

Geodetic datum of the map series

The Bessel ellipsoid of 1841 was selected as base ellipsoid. However, in the GIS practice, it is not enough to present an ellipsoid, the parameters of its position must be defined as well. To do this, identical points must be identified on the triangulation network used as the base of the map and on the modern, Earth centered, Earth fixed WGS84 system (DMA 1986).

This is quite a challenge in the case of the series on the scale of 1:75 000. It is clear that the geodetic datum of the second survey could not have been applied. In the Austro-Hungarian Monarchy, the standard geodetic datum was defined in 1892, after the series had been published, with the Hermannskogel point near Vienna as its geodetic center point. This datum exists in several versions as the some 650 points included in the Third Military Survey were adjusted in 62 different blocks.

World War I interrupted the new adjustment work, based on more accurate calculations. After the war, Austria, Yugoslavia (applying a different Ferro-Greenwich longitude shift, and including the data of the Balkan triangulation carried out by the Monarchy's military cartography before and during the war) and, under a different title (*Jednotné Trigonometrické Sití Katastrání*; S-JTSK) Czechoslovakia used this datum out of the successor states of the disintegrated Monarchy on the basis of adjusting the points found in these countries' own territories.

In the 1880s however, only the coordinates that were later used in the system were available, but not the system itself. International network surveys had been carried out since the beginning of the 1860s within the framework of the Central-European Arc Measurement (*Mittel-Europäische Gradmessung*), from 1864 as European Arc Measurement (Bod 1982, Balla and Hrenkó 1991, Kretschmer et al. 2004, Ádám 2005). Some 600 points' positions were identified on the territory of the Monarchy, except for its most western parts (MGI 1902) and several base lines and astronomical points were measured as well. Supposedly, the series on a scale of 1:75 000 were completed on the basis of such rough, non-adjusted data, which significantly affects the map series' accuracy and the degree of their connectivity with modern maps. Comparing the map coordinates of 650 points based on the adjustments of 1892 it seems that the network divides into several small triangle webs developed around particular astronomically measured points. Faults are relatively minor within these sub webs, however horizontal faults of up to 200 m might occur among the webs. This is what determines the map series overall accuracy.

The Molodensky-type displacement parameters of the point Hermannskogel, according to the coordinates read out from the 1:75 000 scale sheet and resulted from earlier geodetic adjustments (MGI 1902, Homoródi 1952), are the following: $dX = +600$ m; $dY = +205$ m; $dZ = +437$ m.

As it was deduced from the above-mentioned process of the adjustment, there is no such *unified* displacement of the network. The usage of these parameters as general ones results errors in some places of the whole map.

The map series' content in modern projection systems

The third survey concerns the territory of 17 present day countries and the representing software is able to export the map content into the projections used in these countries. In order to achieve this we had to provide the GIS parameters of these projections and their geodetic data earlier (Timár et al. 2006), and also define the approximate position parameters of the Bessel-1841 ellipsoid used during the Central-European Arc Measurement in the previous chapter. In most parts of Austria and the Czech Republic, on the Adriatic coastline and in Croatia, the faults are minor. In Hungary there are several blocks characterized by faults of similar degree and direction: fault is minor in the vicinity of Budapest, but differences of around 100 m or more occur in central and southern Transdanubia and in other directions in the Northern Range and the connecting North-Hungarian territories. In western Slovakia the length and direction of the error is different again. A relatively uniform error is typical in Transylvania (supposedly based on the coordinate data by the Observatory of Sibiu, Hungarian: Nagyszeben, German: Hermannstadt; Timár et al. 2008), Bukovina, Bosnia, and the western and eastern parts of Galicia. The systematic errors in Galicia are derived from the position of the observatories of Krakow, and the L'viv (Lemberg). The greatest errors of slightly more than 200 m occur on the southern and eastern edges (in the vicinity of Shkodra Lake and Tarnopol) of the mapped area. Serious errors of mosaicking appear along the borders of the sheets representing Albania; thus errors of up to exceeding a kilometer occur on three sheets. The possible cause of this blunder could be miscalculated coordinates of one or two geodetic base points.

Systematic errors can be treated through integrating the exported digital map sheet into a GIS system and shifting it into the real position with the aid of one single GCP without further rotation. Through this method local remaining faults can be reduced below 0.5 mm on the map (i.e. 35–40 m in the field).

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